The impact of teaching approaches on effective physics learning: an investigation conducted in five Secondary Schools in Rusizi District, Rwanda

Daniel Uwizeyimana[1], LakhanLal Yadav[2], Theophile Musengimana[2], Jean Uwamahoro[2]

[1]Sector Education Office, Nyarugenge District, [2]University of Rwanda - College of Education

Abstract

The Current Rwandan educational policy fosters the teaching of sciences as a means towards building a knowledge-based economy. This paper describes a research conducted firstly to investigate the current status of teaching and learning physics in Rwandan secondary schools and secondly, to evaluate the impact of teaching approaches on effective learning and performance in physics secondary school classrooms. This study first tested students' understanding of basics concepts and physics problem solving skills. In the second step, the focus of the study analysed to what extent various teaching approaches contribute to improve physics conceptual understanding and problem solving skills among learners. The outcomes of the study revealed the close link between identified difficulties in physics among learners with still commonly used traditional teacher-cantered approaches in teaching physics. In this study, some teaching practices are proposed which can considerably improve the quality of teaching and learning physics in Rwanda.

Keywords: *Physics problem solving, misconceptions in physics, multiple representations, physics teaching and learning approaches.*

Introduction

In Rwanda, like in many other developing countries, the teaching of science, technology and mathematics (STEM) is being prioritised to speed up its economic development (MINEDUC, 2015). However, effective teaching and learning of science in general, and physics in particular has encountered challenges during the past two decades. The lack of sufficient infrastructure and equipment particularly in twelve and nine years' basic education, a systematic and year after year changes into school curricula, as well as noticed lack of sufficiently qualified science teachers are among others factors that have affected effective learning of sciences. In addition to these factors, it is generally observed that the teaching and learning of science (including physics) in Rwanda is still dominated by teacher-cantered approaches that do not promote students 'active learning. The purpose of this study is to investigate the impact of some teaching approaches for improving conceptual understanding and problem solving skills among Rwandan secondary school physics students.

Review of literature.

Physics phenomena are perceived commonly in everyday life and the physics technological aspect makes the modern lifestyle to look easier than it was many years ago. However, the teaching and learning of physics has not always been done efficiently, especially in developing countries (Africa included) (Zewdie, 2014;Millar &Osborne, 1998). This low performance in physics is due to many factors; lack of appropriate teaching materials and qualified teachers, traditional teaching methods, lack of mathematics skills, student epistemologies and misconceptions (Onah, &Ugwu, 2010; Ojo,2001; Zewdie, 2014; Elby, 2001; etc). Another important factor which is behind this low performance as revealed by many studies,it is the physics instruction approaches which is mainly used, while this method of teaching is ineffective for teaching different physical principles (Wieman& Perkins, 2005; Elby, 2001; Jimoyiannis, &Komis, 2001).In many developing countries, when students are asked to solve physics problems, a big number of them do not develop the necessary conceptual understanding, but try to memorize only mathematical formulas (Elby, 2001). Although the lecturing teaching method is the mostly used by physics teachers, students show more interest in physics teaching, when a variety of teaching methods are used (William, 2010). In this regard, teachers have to use a variety of teaching methods in order to optimize the achievement of students by involving them in learning activities, and if not, students tend to memorize what they are taught without conceptual understanding.Another problem which students are facing is a poor motivation and bad attitude toward Physics course. Students often consider physics to be too difficult and abstract course with no utility in life. This low motivation among physics students can be linked to the traditional physics teaching method frequently used by most physics teachers.

Teachers continue to use this traditional teaching approach that demonstrated inability to increase student motivation and performance in physics. For example during physics problem solving activities, some physics teachers start by writing formulas and manipulate mathematical equations to find the final answer, without interpretation and explanations of physical concepts and only students try to memorise them (Elby, 2001). In a well organised group discussions teams by the help of teacher, students should normally participate actively in corroboration with its classmate during Physics problem solving activities (Hofstein&Lunetta, 2003).

As far as physics laboratory is concerned, some physics teachers manipulate themselves the experiments and students may just follow the prescribed procedures without many explanations. In some schools, instead of first organise laboratory, teachers teach only theories and do not put deep emphasis on practices. In order to teach and learn physics, as an experimental science, several laboratory experiments must be organised and students should participate actively while teachers play role of facilitators (Hofstein & Lunetta, 2003).For effective teaching and learning of any science subject (physics included), teachers have to put emphasis on students' participation and let them develop their own knowledge (Cahyadi, 2007).

In this paper, an investigation was first conducted to identify and show some physics teaching and learningdifficulties, as far as physics concepts understanding and practical skills is concerned. Secondary, the investigation focused on analysing the current status of physics teaching methods and to suggest new teaching approaches that are suitable for the implementation of the Competence Based Curriculum (CBC) and can help to improve students' motivation and conceptual understanding of physics.

Research methodology

This study was conducted in Rusizi District, located in the Western Province of Rwanda. Rusizi region was considered for the study because the principal investigator for this work was then the Sector Education Officer in that region. The investigation involved 4 Secondary Schools all of which had physics subject major in their programme. In addition, all the schools involved were public and government supported schools with relatively good standards in terms of infrastructure, laboratory equipment and qualified teaching staff:

Those schools are: Ecole Secondaire Bugarama, Ecole Secondaire de Gishoma, Ecole Secondaire de Nkomboand Groupe Scolaire Gihundwe. The sample of schools selected represent a good picture of secondary schools in other Districts in Rwanda and therefore, the results from this study can be extrapolated to represent the status of the whole country. In total, 127 people were involved in the investigation including122 senior six physics students and 5 qualified physics teachers. Both purposive and random sampling strategies were used to find the sample size. Quantitative and qualitative data were collected using questionnaires, interviews and classroom observations. Questionnaires were distributed to both students and teachers and classroom observations were conducted during teaching/learning activities by observing methods used. For data analysis, tabulation, graphic, coding and comparison were used.

The questionnaire used to collect data had both close and open ended questions totalizing 29 items for both students and teachers' questionnaires. The questionnaire for students had 6 open ended questions, while that of teachers had 5items for open ended questions to test students and teachers' physics cognitive and practical skills. For class observations, the focus was on checking the lesson plans, the teaching methods, interaction between teachers and learners, use of laboratory and improvisation and students' motivation. An interview was also arranged for physics teachers and students to collect additional information. After data collection, these were analyzed and interpreted using tables and computation of percentages.

4. Presentation and discussion of findings

4.1. Investigation of students and teachers' cognitive and practical skills in physics.

Mechanics is considered as a fundamental and basic prior to learning other topics in physics. In this study, a few questions of physics (mechanics) were given to students to test their conceptual understanding. Only some of them shall be presented here to clearly show the importance of the investigation. It should be mentioned that by the time students were given the questionnaire, they all had covered the classical mechanics module during previous years.

The first question asked to the students was to choose the best statement on the following question. When a loaded pick-up makes a head-on collision with a motorbike. During this collision: (i) the pick-up is exerting much more force on the motorbike than the motorbike does on the pick-up (ii) the motorbike is exerting much more force on the pick-up than the pick-up does on the motorbike (iii) the pick-up is exerting force on the motorbike but the motorbike does not exert on the pick-up, (iv) the pick-up and motorbike are exerting the same amount of force on each other. Only 24.6% of all respondents gave a correct answer (iv), which is consistent with the third law of Newton. The majority of students have a misconception that the heavier objects exert a greater amount of force on the lighter ones.

The second question was to agree or disagree whether a body with zero velocity can have a non zero acceleration at the same time and to give an example. On this question, only 25.4% gave a correct answer, yes and none of all respondents gave a correct example. While a very familiar example is: when a ball is thrown up vertically its velocity at high point is zero and its acceleration is down ward.It is important to mention that students involved in this survey have all completed a chapter on gravitation. The results obtained clearly show that many students cannot apply concepts of velocity and acceleration appropriately. It also shows that physics teachers do not help their students to construct and understand the physics concepts but they transmit only the knowledge to students.

The third question was to show the direction of net force acting on an oscillating bob when it is at point P as shown in figure 1.

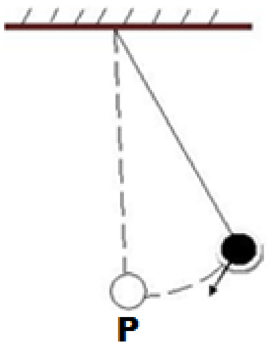


Figure 1: Figure of the question 3 asked to the learners.

At point P, the direction of the force on the bob is: (A) rightward, (B) leftward, (C) downward, (D) upward

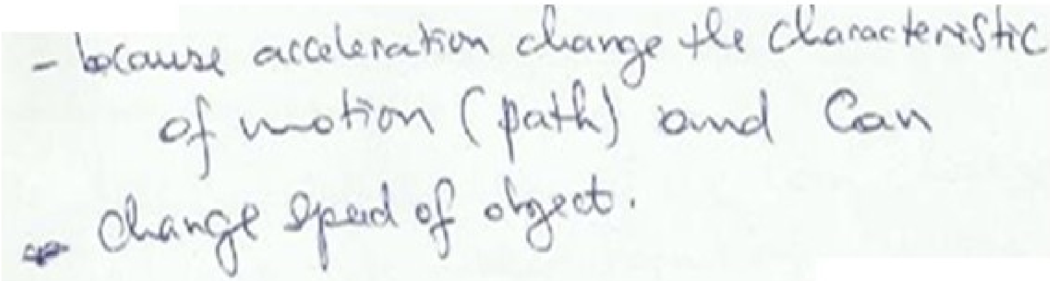
On this question, only 6.5% gave a correct answer (D), that the net force acting on a bob at point P is directed upward, 36.9% responded the answer B (a misconception that the net force will have the same orientation with the bob motion) and 36.1% responded answer C (a misconception that this force is the weight of a bob).

From these three questions related on students' understanding of physics concepts/principles, in summary, only an average of 18.8% students have succeeded to the asked equations. On the other side we also tested teachers' cognitive and practical skills, we asked them to explain briefly how they teach the concept of acceleration in physics class. For this question, 2 out of 5 (40%) tried a little bit but the remaining 3 showed that they do not teach the concept of acceleration appropriately. This is an example of answer provided by one physics teacher to the following question:

Question

You wish to explain the concept of "acceleration" in your physics class. Explain briefly how you will do it.

Answer


- because acceleration change the characteristic of motion (path) and Can
- Change speed of object.

According to this example of an answer given by one teacher, it is very clear that some of physics teachers are not able to efficiently transfer the cognitive and practical skills of physics to their students.The survey conducted show that both teachers and students still have major problems in physics conceptual understanding.

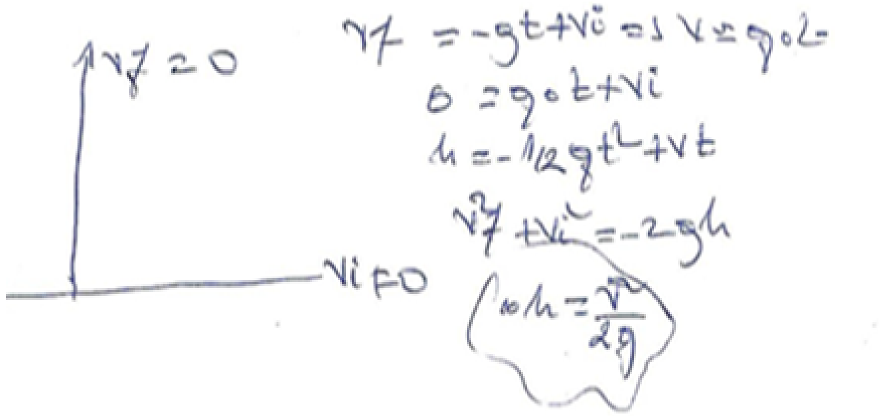
Question four tested the ability of students to use multiple representation, for better description of physics concepts/principles. In fact, physics knowledge should be described using different representations:

words, pictures, diagrams, graphs or mathematical relations. In this research, we asked the students to describe the relationship between velocity, acceleration and time duration; for an object moving with initial velocity v_0 in positive x-direction, when a constant net force acts on that object to cause an acceleration a of that object in the + x-direction and after time t, the velocity of the object becomes v, using different ways (i.e. using different representations).Find here below the question asked and an example of answer given by one student:

Question

An object has initial velocity v_o in + x- direction. A constant net force is acting on the object which causes an acceleration a of the body in the + x-direction. After time t, the velocity of the object becomes v. The velocity v is related to v_o, a, and t, describe it using different ways (i.e. using different representations) which you may think about in the space provided bellow:

Answer



For this question, a clear majority of respondents, 59.0% wrote only the formula, whereas 32.8% gave wrong formulas without any other comments or description form. Only 8.2% of all respondents gave this relationship using the formula with words description and only two among them provided good graphical description.

This study revealed that students rush to writing physics formulas and do not care of explaining the concepts and principles behind formulas. A good physics student would normally use mathematical, graphical and diagrammatical description to explain clearly the physics concepts/principles (May & Etkina, 2002). The same question was asked to the teachers, all respondents (or 100%)described this relationship using only formula. It is important that physics teachers use appropriate representations to discuss physics knowledge and emphasize explicitly the relation between different representations used for discussion (Van Heuvelen, 2001).

Question six was given to test the ability of students to organise their knowledge in physics. Good scientists should have ability of knowledge organisation, in order to remember detailed information (Elby, 2001). For this study we asked the students to summarize very important concepts/principles they learnt in mechanics. This is the question and answer given by one of them:

Question

You have already completed mechanics course last year. In that course you leant some very important principles which you summarized at the end of this course (we assume). Mention in the space provided below, how you summarize very important principles of mechanics.

Answer

1st the moment of Inertia of an object helps in daily life
How the body circulate on its orbit

On this question no one (or 0%) of all respondents could summarized well the concepts/principles they learnt in mechanics in senior five. From the results on this, it is clear that students do not know how to organize their knowledge in an effective way. This is well consistent with what was observed in the students' notebooks. In the notes provided by teachers, they often jump immediately to the next chapter without summarizing the previous lesson. In fact, when teachers were asked summarise important concepts/principles they taught in mechanics, none of 5 respondents (0%) could do this. Science subjects (physics included) are characterized by many complex theories (Hofstein & Lunetta, 2003), knowledge organisation skills are very important for the students to understand them.

Problem-solving ability is considered as one of important skills in teaching and learning (Van Heuvelen, 2001). In this regard, students were asked how difficult it is, for them to solve a physics problem or exercise if they never seen a similar one before. Only a few of them (8.2%), confirmed to not have much difficulties in solving a new physics problem or exercise. Similarly, teachers were asked to explain the approach (important steps) they usually use in physics problem solving class. All teachers (or 100%) responded that they follow the following steps: -Identification of data, Identification of unknown and then identification of formulas to be used and calculation. No one (0%) could prove to have enough skills in physics problem solving. During physics problem solving, teachers are required to help their students to follow a systematic way, which is to start by analysing the problem, constructing the solution and checking it (if not okay, revising all these steps) (Hofstein & Lunetta, 2003).

Finally, an investigation was done to evaluate the students and teachers' laboratory skills. For this, we asked the studentsto enumerate the laboratory skills learnt during their physics experiment classes. The majority of respondents, 89.3% reported only by giving the list of the experiments they have done without mention of the skill learnt from those experiments. Only 10.7% of the students confirmed that they have learned measurements skills and how to do a laboratory report-writing. Since physics is an experimental sciencephysics teachers should give more emphasis on laboratory classes and make sure that students get enough laboratory skills. When students perform well their lab experiments they become motivated and performers. When teachers were asked to list laboratory skills they want their students to develop in physics laboratory class, only 2 out of 5 or (40%)revealed that they want their students to develop the report-writing skills, observation and manipulation of laboratory apparatus. From these results, it is clear that many teachers do not know the laboratory practical skills their students need to develop in laboratory classes. The figure 2 gives a summary of results found during this research, for students and teachers cognitive and practical skills.

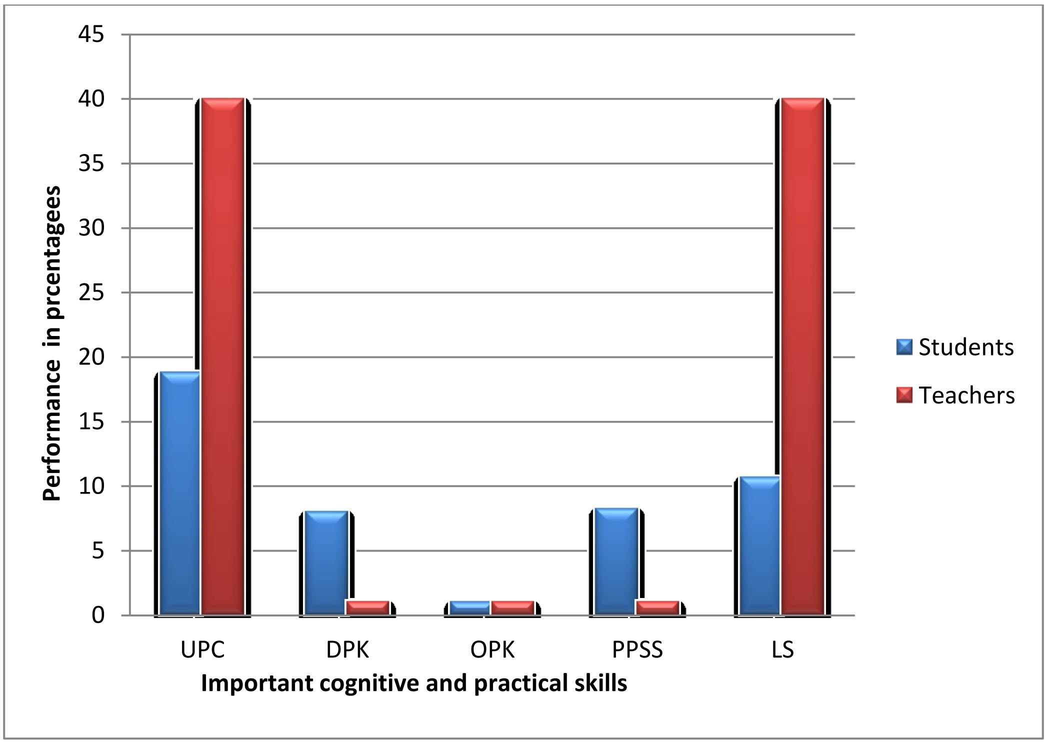


Figure2: *Students and teachers' cognitive and practical skills for teaching and learning physics (UPC: understanding of physics concepts, DPK: Description of physical knowledge, OPK: Organisation of Physical Knowledge, PPSS: Physics Problem Solving Skills, LS: Laboratory skills)*

4.2 Physics students and teachers' perceptions on used approaches

The second part of this work consisted in investigating what extend teachers use the best practices in teaching physics. A particular focus was on major constituents of any lesson plan and step to follow while teaching physics subject. Best approaches in the teaching of physics include: discussion about instructional objectives before starting physics lesson, consideration of prior knowledge before starting new topic, construction of students knowledge, inclusion of physics real-life examples, improve the working in groups or group discussions, use of laboratory and improvisation and use of inductive methods. In the following section, important findings from the investigation are presented and discussed.

- Instructional objective (IO)

During the investigation students were asked whether their physics teachers discusswith them instructional objectives before starting lessons. The results obtained indicated that only 29.5% of students confirmed to have had instructional objectives discussion with their teachers. In this regard, 60% of physics teachers agreed discussing instructional objectives with their students. In addition, from observation made in classrooms, it was noted that a big number of teachers do not discuss with their student instructional objectives. Teachers should discuss with students about the instructional objectives and make those objectives as detailed and specific as possible in order to make sure that students know what important knowledge and skills they must achieve (Felder, Donald, Stice & Rugarcia, 2000).

- *Consideration of prior knowledge (CPK)*

In modern Education, it is better to start a new topic in any course, physics included, by investigating what students know about that topic before. Students always have knowledge on any new topic. Therefore, teachers have to work as facilitators and help students to understand new knowledge using the students' early knowledge. In this regard, we asked students whether their teachers investigate their prior knowledge before starting the new topic. The information collected shows that only 32% of the students confirmed that their teachers consider their prior knowledge before introducing a new physics topic. This information is however different from the one by teachers as 80% of them claimed to consider the prior knowledge of the students before starting a topic. Teachers must consider the prior knowledge of their physics students and help students to understand by themselves any new physics topic (Redish 2002).

- *Construction of knowledge (CK)*

Learning involves active construction of meaning (Fahraeus, 2013). In this investigation, students were asked if they construct their own knowledge and teachers act as facilitators. From the findings, it appeared that close to a half of students involved in the study (49.28%) confirmed to try to construct their own knowledge. This is not the case for their class teachers (40%) who claimed to let their students develop their own ideas before and during a physics lesson. Students ability to construct good models are required for a better physics concepts understanding (Redish, 2002).

-*Inclusion of daily-life examples during teaching (IDET)*

Inclusion of real-life examples during physics instruction encompass many characteristics of constructivism. For this case, students were asked if they connect physics concepts with daily-life examples. On this item, 42.6% of respondents reported that they frequently connect physics concepts with real-life examples. On this item, even though most of the teachers (80%) claim to use every day life examples during their teaching, the response from students indicated that less than a half of them who participated in the study (42.6%) can link the concepts learned in physics and the real world.

-*Working in groups discussion (WGD)*

Group work as a teaching strategy enables students to learn by collaborating among themselves as a team and work towards a common goal. In this study, 36.1% of students involved asserted that they often work in groups. On the other side about 40% of teachers participated in the study confirmed that they promote students to use peer instruction when they are teaching physics. Not only students should be encouraged to work in group, but also have time to discuss among themselves on the learned topic. During class observation, it was observed that the majority of teachers do not allow group discussions among learners. Group work enables students to learn by collaborating among themselves as a team and work towards a common goal. The lack of cooperation among students leads to the low performance, low interpersonal relationships, low perceptions of greater social support and low self-esteem (Redish, 2002).

-Use of laboratory and improvisation (ULI)

In this study, the use of laboratory experiments was evaluated. The findings indicate that up to 68% students participate (carry out)in the lab experiments. However, it should be noted that even if many students claims to often carry out the lab experiments, they do not participate actively. In fact, 77% of students questioned revealed that their teachers perform experiments while themselves are passive observers. From our investigation, we noted that whenever lab materials for experiments were not available, a very few number of students (23.4%) confirmed to have been taught with the use of local materials (improvisation). Looking on the side of physics teachers, 60% of respondents claim to make use of lab experiments and sometimes, explore the use of locally made (improvisation) lab equipment. Although the performance of teachers in regards to the use of laboratory and improvisation was found to be quite good (70%), it contradicts the information obtained from learners that labs experiments is generally not sufficiently used in physicsschools.It is important that teachers carry out laboratory experiments in every course necessitating it and helps student to participate actively during Physics lab activities, because laboratory helps students to master basic physics concepts and when teachers don't have standard teaching lab materials, they should make their own materials by using less expensive and local materials (Aina, 2013). Effective laboratory classes are very important to develop problem solving and physics conceptual understanding skills of the students (Trumper, 2003).

-The use of many resources in learning physics (UMRL)

The mastery of science concepts is well achieved, when many different teaching and learning resources are used. On this point, 86.1% revealed that apart from class notes they read other books, whereas 13.9% revealed that apart from the class notes they do not read other books. Teachers were also asked if they recommend their students to read many other books apart from the class notes. All the teachers (100%) confirm that they recommend the students to read books. This concurs well with the students' responses. Teachers should encourage and orient their students to read many other books rather than consulting only notes they have in physics class.

-Use of inductive approach (UIA)

In this investigation, students were also asked about the common methods teachers use when they teach them physics. 55 % students reported that their teachers frequently explain, derive relations (formulas) then students take notes. This kind of teaching called teacher-centered approach and referred as deductive or tradition method is not an effective mode of teaching (Fahraeus, 2013).On the other side of the teachers, they all (100%) responded that they always concentrate much in teaching activities while their students listen carefully in discipline (i.e. deductive method). From this research It is clear that physics teachers still use traditional methods of teaching. Teachers are required to help their students to become active learners and construct their knowledge (Fahraeus, 2013). Thus, teacher should shift from this traditional (deductive and teacher-centered) method of teaching to active (inductive or learner-centered) methods of teaching. Figure 3 gives a summary on students and teachers perceptions on used approaches during teaching and learning physics in Rwandan secondary schools.

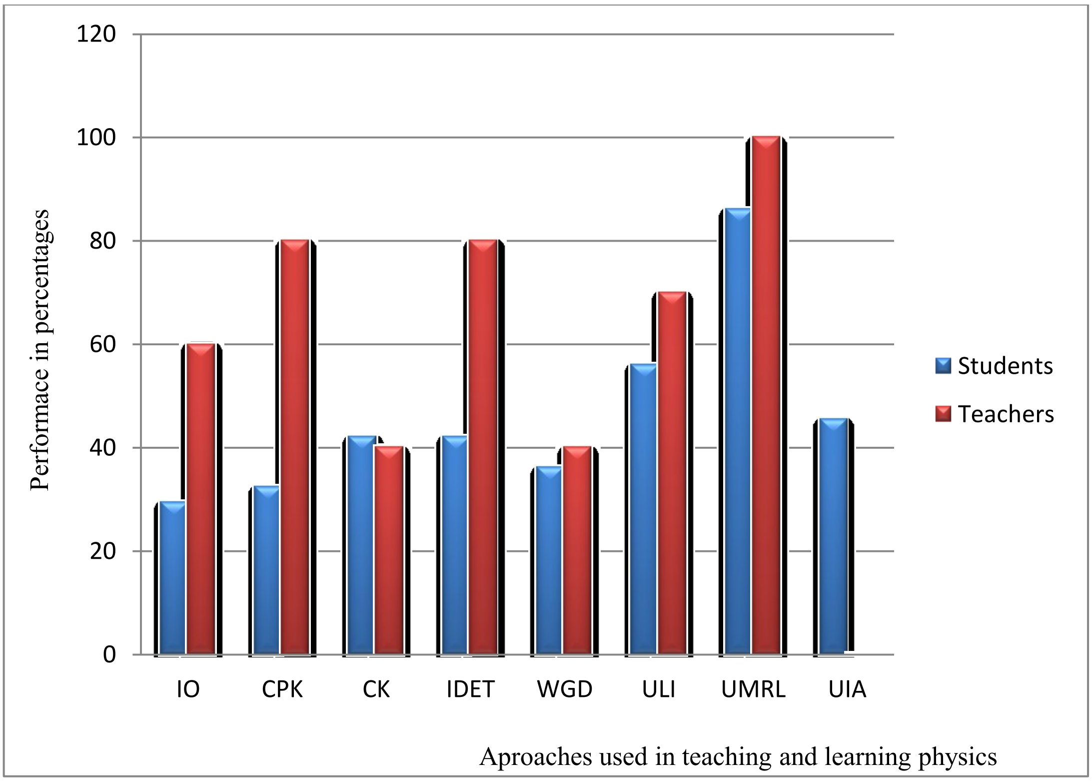


Figure 3: Students and Teachers' perceptions on the methods used in teaching and learning physics.

5. Conclusion

This study was purposefully firstly, to investigate the current status of students and teachers understanding physics concepts in mechanics as well as learning skills. secondly, the research study analysed the relationship between identified problems in teaching and learning of physics and the teaching approaches used during the teaching and learning process. The study sample comprised 122 physics students and 5 teachers from the southern province. In general, the analysis of collected data indicates that both physics students and teachers do not have cognitive and practical required in learning and teaching physics. The results from conducted investigation also revealed that these barriers or gaps in learning and teaching physics are closely linked with traditional teacher-centered teaching approaches which are commonly in use in Rwandan secondary physics classrooms. Particularly the results from this analysis show that all best practices known for improving the learning of physics were not adequately used by physics teachers in Rwanda. On the basis of the study outcomes and in order to improve physics learning in terms of mastering physics concepts, problem solving and practical skills, some teaching strategies are proposed. During the teaching and learning of physics, it is recommended that physics teachers: consider the importance of detailing instructional objective and student prior knowledge and beliefs to help them overcome misconceptions. Teaching and learning approaches recommended in this study will highly be helpfully in the implementation of Competence Based Curriculum in schools, and therefore improve the performance of students in physics. We believe that the findings and recommendations from this study, if appropriately applied would contribute much in improving teaching and learning of science in general, and physics in particular.

References

Aina, K. J. (2013). Instructional materials and improvisation in Physics class: Implications for teaching and learning. *IOSR Journal of Research & Method in Education.* 2 (5),38-42.

Cahyadi, M. V. (2007).*Improving teaching and learning in introductory physics*. Doctoral dissertation, University of Canterbury, Christchurch

Elby, A. (2001). *Helping physics students learn how to learn*. American Journal of Physics, Physics Education Research Supplement, 69 (7), 54-64.

Fahraeus, A.W.E.(20013). Learner-Centered Teaching: Five Key Changes to Practice. *Journal of the Scholarship of Teaching and Learning,* 13(4), 1- 6.

Felder, M. R., Donald, R. W., Stice, J. E. & Rugarcia, A. (2000). The future of engineering education: teaching methods that work.*Chem. Engr. Education,* 34(1), 26–39.

Hofstein, A., & Lunetta, V. N. (2003). The laboratory in science education: Foundations for the twenty-first century. *Wiley Periodicals, Inc. Sci Ed 88:28 – 54, 2004. Published online in Wiley InterScience (www.interscience.wiley.com).*

Jimoyiannis A., & Komis, V. (2001). Computer simulations in physics teaching and learning: a case study on students' understanding of trajectory motion.*Computers &Education*, 36, pp. 183-204.

May, D.B., & Etkina, E. (2002). College physics students' epistemological self-reflection and its relation to conceptual learning. *American Journal of Physics*,70(12), 1249-1257.

MINEDUC, 2015. Summary of curriculum frame-work Pre-Primary to upper Secondary 2015.

Millar, R., Osborne, J., eds., 1998. Beyond 2000: Science education for the future. The report of a seminar series funded by the Nuffield Foundation. London: *King's College London, School of Education*. [Online] Available at: http://www.nuffieldfoundation.org/beyond-2000-science-education-future

Ojo, M.O. (2001). Problems of teaching Science and Mathematics in Nigeria. *A paper presented at the Train-the Trainers workshop for Science and Mathematics teachers in Colleges of Education in Six Geo-political zone of Nigeria.*

Onah, D.U., & Ugwu, E.I. (2010). Factorswhich predict performance in secondary school physics in Ebonyi north educational zone of Ebonyi State, Nigeria. *Advances in Applied Science Research***,** 2010, 1 (3): 255-258

Redish, E.F. (2002). Teaching Physics with the physics suite. London: *John Wiley and Sons*.

Trumper, R. (2003). *The Physics Laboratory: A Historical Overview and Future Perspectives.Journal of Science and Education*, Vol.12, pp. 645–670.

William, B (2010). Instructional Methods for Teaching Social Studies: A Survey of What Middle School Students Like and Dislike about Social Studies Instruction: *University of Central Florida*.

Wieman, C., & Perkins, K. (2005). Transforming Physics Education. *Published in Physics Today*, 58 (11), 36.

Zewdie, Z. M. (2014). An investigation of students' approaches to problem solving in physics courses. *International Journal of Chemical and Natural Science*, 2(1), 77-89.